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San José State
UNIVERSITY
FOUNDATION

Office of Sponsored Programs
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January 14, 1999

CALFED Bay-Delta Program
1416 9th Street
Sacramento, CA 95814
Attn: Cindy Darling

Dear Ms. Darling:

Enclosed is the original plus two copies of a proposal entitled "Assessment of Ecological and Human Health Impacts of Mercury in the Bay-Delta Watershed," to be directed by Dr. Kenneth Coale and Mark Stephenson. We are requesting a total of $3,700,000 for the period beginning October 1, 1999 and ending September 30, 2002.

Studies outlined in this proposal will determine what are the most bioavailable sources of mercury in the watersheds, where the most active methylation is taking place downstream, what environmental factors accelerate the methylation of mercury in sediments, if mercury is high enough in sports fish to trigger health advisories, and whether mercury is high enough to affect birds in the Delta. These studies will recommend which restoration projects have the potential to enhance methyl mercury production in the Delta.

San José State University has complete confidence in Dr. Coale's and Mr. Stephenson's capabilities to carry out the proposed project. If you have any questions on administrative matters, contact Dr. Nabil Ibrahim, Acting Associate Vice President for Graduate Studies and Research, at (408) 924-2480; for program matters contact Dr. Kenneth Coale or Mark Stephenson, Project Co-Directors, at (831) 755-8655 or (831) 633-0253, respectively; and for fiscal matters contact Carol Sooter, Associate Director of Contracts and Grants, at (408) 924-1430.

Any contract, grant or other agreement resulting from this proposal should be between your agency and San José State University Foundation. The Foundation is a legally recognized auxiliary organization of San José State University.

Sincerely,

Edd Burton
Associate Vice President for
Institutional Planning and Academic Resources

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Encl.

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STATE OF CALIFORNIA—THE RESOURCES AGENCY PETE WILSON, Governor

DEPARTMENT OF FISH AND GAME
1416 NINTH STREET
P.O. BOX 944209
SACRAMENTO, CA 94244-2090

Rebecca Fawver.
CALFED
1416 9th st.
Sacramento, CA.
95814

Date: January 14, 1999

Dear Rebecca,

Please find enclosed a proposal entitled "Assessment of Ecological and Human Health Impacts of Mercury in the Bay-Delta Watershed" to be submitted to CALFED as a designated action. Studies outlined in this proposal will determine what are the most bioavailable sources of mercury in the watersheds, where the most active methylation is taking place downstream, what environmental factors accelerate the methylation of mercury in sediments, if mercury is high enough in sports fish to trigger health advisories, and whether mercury is high enough to affect birds in the Delta. These studies will recommend to CALFED which restoration projects (such as dredging, levee building, canal building, disposal of dredge spoils on wetlands, creation of wetlands, etc.) CALFED should fund based upon their potential to enhance methyl mercury production in the Delta.

Sincerely,

Mark Stephenson

Mark Stephenson
Director, Marine Pollution Studies
California Department of Fish and Game
P.O. Box 747
Moss Landing, CA. 95039
(831) 633-0253
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Assessment of Ecological and Human Health Impacts of Mercury in the Bay-Delta Watershed

--a proposal to the CALFED Bay-Delta Program, by--

PRIMARY CONTACT: Mark Stephenson, Director, Marine Pollution Studies Laboratories, California Department of Fish and Game,
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Assessment of Ecological and Human Health Impacts of Mercury in the Bay-Delta Watershed

EXECUTIVE SUMMARY

Background: Eighty-eight percent of the mercury produced in the United States between 1850-1980 was mined in the Coast Range of California. There were 320 mercury mines including several of the world's largest. Most of the mercury was transported across the Central Valley and lost in Sierra Nevada placer gold mining activities (R. Churchill, personal communication). As a result widespread mercury contamination has occurred in the Coast Range and Sierra Nevada waterways and downstream in the Central Valley Rivers and the Sacramento-San Joaquin Delta Estuary (Bay-Delta). Recent studies have determined that large amounts of mercury are still being transported annually into the Bay-Delta from both the Coast range and from the Sierra Nevadas (Foe and Croyle, 1988; Larry Walker and Associates, 1987; Roth *et al.*, 1998). Not all the sources of this mercury have yet been identified, though Cache Creek in the Coast Range appears to be a major source.

Methyl mercury is a potent human neurotoxin, with developing fetuses and small children being most at risk (White *et al.*, 1995). The principal route of human exposure is through consumption of mercury contaminated fish. Health advisories and interim health advisories have been posted in the Bay-Delta recommending no consumption of large striped bass and limited consumption of other sportfish species, with even lower consumption rates recommended for pregnant women and small children (OEHHA 1994, San Francisco Regional Water Quality Control Board, 1995). More recent sampling has demonstrated high concentrations in other species suggesting that the contamination is more widespread than previously thought and that additional advisories may be warranted. Elevated concentrations of mercury in fish tissue may also represent a hazard to piscivorous wildlife. Species most at risk are fish-eating birds and mammals.

An objective of the CALFED Ecosystem Restoration Program is to restore aquatic habitat and increase fish abundance in the Central Valley and Bay-Delta. However, unless there is a successful mercury control program, some of the new fish are likely to have the same body burden as organisms already present in the Estuary. Increased fish stocks would likely result in an increase in fish catches and an increase in mercury consumption by the California angling public. And, because restoration activities involving reflooding wetlands may result in a higher production of methyl mercury, this may increase the bioaccumulation of mercury in fishes. As a result, a successful CALFED Ecosystem Restoration Program may exacerbate an already significant human health problem.

Inorganic mercury is converted to the methylated form (methyl mercury) by microorganisms, primarily sulfate reducing bacteria. Factors which promote methyl mercury formation in the Bay Delta system are not well understood, though temperature, organic matter, redox potential, salinity, pH and inorganic mercury concentration are important in other systems (Gilmour, 1995). Key factors controlling methyl mercury production in the Central Valley are not known although there does not seem to be a strong correlation with inorganic mercury concentrations in sediment and water (Suchanek *et al.*, 1997).

Strategy: The goal of the CALFED Mercury Water Quality Common Program is to reduce concentrations in fish tissue to levels that do not pose a wildlife or human hazard. Our hypothesis is that not all the mercury moving into the Bay-Delta is biologically available. Studies need to be undertaken to determine what are the most bioavailable sources of mercury in the watersheds, where the most active methylation is taking place downstream, and what environmental factors accelerate the methylation of mercury in sediments. Future targeted remediation can then be directed in a cost-effective fashion at sites that contribute the majority of biologically available mercury to the system. The result of remediation should be a relatively rapid decrease in mercury concentrations in fish tissue close to the sources and a slow, gradual reduction (on the order of several decades) in mercury stocks throughout the rivers and Bay-Delta system. Unfortunately, so much mercury is present in sediment in the main stem rivers and in the Bay-Delta that fish tissue concentrations may only be affected by identifying and managing sites with high methylation potential. This could minimize mercury conversion to an organic form while allowing clean sediment to gradually bury and reduce the bioavailability of the material already present. The result should be a gradual

reduction in Bay-Delta fish tissue concentrations. A series of studies are outlined below to determine the information needed to begin implementing this strategy.

The plan is fourfold. **First:** The primary sources of mercury and methyl mercury to the Bay-Delta system must be determined. Mass loading studies are needed to augment past efforts by surveying new areas, to obtain methyl mercury loading estimates. Key areas that lack data and need additional information include Cache Creek (Tasks 1 and 5), the Mokelumne/Cosumnes rivers, the San Joaquin river and the entire Sacramento River watershed (Task 1). Filling these data gaps will provide the information needed to determine which watersheds/rivers are most important in transporting methyl mercury and total mercury into the Bay-Delta system.

Second: It is necessary to obtain data on mercury levels in fish to better evaluate the health risk posed to humans and wildlife by local fish consumption. The levels of mercury in sport fish will be compared to guidelines for the protection of human health, to assess whether additional fish advisories are needed (Task 2). In addition, the levels in small fish will be compared with levels known to cause reproductive impairment in birds (Task 3). Companion laboratory studies will simultaneously be conducted on bird eggs (Task 3) injected with increasing concentrations of methyl mercury to determine the thresholds for reduced hatching success and developmental abnormalities. These levels will be compared to concentrations in field collected eggs of piscivorous birds to ascertain whether impairments are likely in Cache Creek and elsewhere around the estuary. Both sets of studies will provide critical information on the human health and wildlife risk posed by consumption of mercury contaminated fish. The studies will also help establish safe target fish tissue levels to guide future remediation efforts and to provide a baseline of mercury data in fish tissue and bird eggs that can be used in future monitoring programs to assess trends and management success resulting from CALFED activities.

Third: The bioavailability of mercury from various sources and at various points along the watershed must be determined. Many of the strategies involve reducing loadings to the Delta, however, information regarding the bioavailability of mercury from loading sources is absent or limited. The consensus of many researchers in California and elsewhere is that much of the mercury contaminated sediment entering the estuary from both the Sierras and Coast Range may have little bioavailability. If so, remediation of this material would be expensive and do little to reduce mercury levels in fish. Studies will be undertaken to determine the bioavailability of the different kinds of mercury-contaminated sediment present in tributary watersheds, as well as contaminated sediment once it is transported into the estuary. The result should, once it is coupled with the loading information from the same watersheds (Task 1), provide definitive information on which tributary waterbodies are most important to remediate for both local and downstream mercury controls (Task 4). The studies should also provide the first information on where the majority of mercury is being methylated in the Bay-Delta. This information may prove crucial in devising future management strategies to minimize estuarine methyl mercury production and reduce accumulation in the aquatic food chain.

Fourth: Pilot mine remediation feasiblity studies will be conducted in Cache Creek. The methodologies developed in this series of studies will be applicable to mine remediation sites in the entire watershed. Decreasing selective loading from key mine sites may ultimately be an effective way of lowering the methyl mercury levels in downstream sport fish. Several known mine sites in the Cache Creek drainage which export potentially bioavailable mercury will be studied to determine where in the mine complex the bioavailable mercury is being produced, how best to clean up the site, the cost of cleanup, and how to monitor the effectiveness of the cleanup effort (Task 5). Conducting these studies will refine our understanding of (1) the linkages between the amount of mercury coming from mines and mercury levels in invertebrates and fish, (2) the relationship between mercury in low trophic level bioindicator organisms as well as accumulations in higher organisms of concern from both a wildlife and human health perspective and (3) which organisms will be the most effective in monitoring the success of mine remediation efforts.

Finally: The Department of Fish and Game will integrate the loading, health risk, bioavailibility, and mine remediation studies into a cohesive research program. This will allow us to determine many of the impacts of mercury, where mercury is coming from, and how to remediate. An initial review of the research plans, outlined in this proposal, will take place by expert scientists, Department of Fish and Game, interested public, and CALFED to insure that the best science is done. At the halfway point, another review will follow to allow for midcourse corrections. All participants will submit quarterly, mid project and final reports so that ongoing progress can be monitored and any problems can be identified and addressed at an early stage. The Department of Fish and Game

will prepare a final summary report that addresses all the major objectives of this study and includes recommendations for remediation as well as additional research that needs to be conducted. One of the goals of the final summary will be to recommend which CALFED restoration projects (such as dredging, levee building, canal building, disposal of dredge spoils on wetlands, creation of wetlands, etc.) should or should not be funded based upon their potential to enhance methyl mercury production in the Delta.

SCOPE OF WORK

Task 1: Quantification of Mercury Loads to the Bay-Delta System from Tributary Watersheds

Determination of the relative amounts of all major sources of estuarine methyl mercury is critical to deriving a cost-effective strategy to reduce production of the material and decrease concentrations in biota. All the methyl mercury in fish within the estuary is the result of either organic mercury being transported into the estuary in the major rivers or of inorganic mercury carried in from the different watersheds and methylated *in situ* in estuarine sediment. Studies are outlined in this section to determine the importance of methyl mercury loads and of estuarine production of methyl mercury from sediment contaminated with inorganic mercury from the various watersheds. The results will be used in two ways. First, the methyl mercury loads will be compared with similar estimates from estuarine sediment to determine the relative importance of each water body in the direct production of organic mercury. Second, the sediment load estimates from each basin will be coupled with estimates of methyl mercury production from this material once in the estuary to ascertain the indirect importance of material from the basin in the methylation process. The two sets of results should provide conclusive evidence of the relative importance of each watershed in the creation of methyl mercury and help focus future remediation efforts on the most important watersheds.

Subtask 1A: Investigation of Sacramento River Mercury Sources

Lead Participant: Sacramento River Watershed Program

Inorganic mercury loading studies have been done for the Sacramento River, the source of 80 percent of the freshwater entering the estuary (Foe and Croyle, 1998; Larry Walker and Associates, 1997; Roth *et al.*, 1998). However, most of this data was collected during a single hydrologic cycle (wet year) and included little methyl mercury data. Additional loading information is needed for the Sacramento River. The study should emphasize the collection of more total, dissolved and methyl mercury loading information in the context of sediment and water fluxes. The study should also seek to determine the location of the principal upstream sources of both methyl mercury and also of the most easily methylated inorganic mercury forms. The Sacramento Watershed Program has committed to conducting total mercury studies over the next two years and is contemplating the addition of methyl mercury monitoring at several sites and sharing the information with this program.

Subtask 1B: Investigation of Mercury Sources from Other River Systems (Cosumnes, Mokelumne, and San Joaquin Rivers)

Lead Participant: Central Valley Regional Water Quality Control Board

Loading studies are also proposed for the Cosumnes, Mokelumne and San Joaquin Rivers. While the three watersheds are much smaller than the Sacramento basin, extensive placer gold mining occurred in all three of these drainages. In addition, several large mercury mines exist in the Southern Coast Range and drain to the San Joaquin River. Therefore, all three watersheds may be significant sources of estuarine mercury. Loading studies will be conducted in each watershed for two hydrologic cycles and estimates will be made of the loads of total recoverable, dissolved and methyl mercury from each basin. Estimates of sediment transport will also be made. As noted above, the results will be analyzed to determine the annual methyl mercury load exported from each watershed and also the methylation potential of sediment from the basin once transported into the Bay-Delta.

Subtask 1C: Quantification of Mercury and Methyl Mercury Loads from the Cache Creek Watershed and the Yolo Bypass

Lead Participant: U.S. Geological Survey

Loads of mercury and methyl mercury will be quantified at selected locations in the Cache Creek watershed during an 18-month period that includes two wet seasons. Several existing gauging stations will be used and four new ones constructed. Six or more gauges will be instrumented for continuous monitoring of flow and turbidity, which will be used to estimate suspended sediment and total mercury concentrations, compute accurate mercury loads, and coordinate sampling during storm events at maximum discharge and sediment loading. Water quality and sediment concentrations will be monitored at gauging stations on at least five occasions during the study period. Relatively conservative trace elements (e.g. Boron, Chloride) will be used to distinguish natural mercury sources such as thermal springs from anthropogenic sources such as abandoned mine sites.

Subtask 1D: Special Storm Event Study of Mercury Loading in Cache Creek

Lead Participant: Central Valley Regional Water Quality Control Board

Harley Gulch and Sulfur Creek have been identified as major sources of total and bioavailable mercury in Cache Creek (Slotton *et al.*, 1997; Foe and Croyle, 1998). The U.S. Geological Survey will install flow gauges on both Creeks and collect general loading information for each tributary (see Subtask 1C above). However, it is felt that additional intensive sampling will be required at each location to fully characterize the loads as most material will probably move off during short intense winter storms. Additional intensive event based monitoring is proposed for both sites to determine total and methyl mercury export. Sampling would target winter storms or any other special events identified to be major causes of off site mercury movement.

Subtask 1E: Utilization of Lagrangian Sampling for the Identification of Unknown Mercury Sources in the Cache Creek Canyon

Lead Participant: San Jose State University Foundation @ Moss landing Marine Laboratories

Studies conducted to date in the Cache Creek watershed have demonstrated that most of the mercury export occurs during short winter high flow rain runoff events (Foe and Croyle, 1998). The largest source of mercury was not identified. It appears to be located in the remote inaccessible portion of the Cache Creek canyon between the confluence of the North and South Forks and Bear Creek. If sampling by the U.S. Geological Survey during year one (Subtask 1C, above) confirms the presence of this unidentified source, then one or more Lagrangian special studies will be undertaken during year 2 to identify and quantify the loads from the source. Lagrangian sampling involves monitoring the same mass of water as it flows through a watershed along with all tributary inputs to pinpoint sources and dilution flows.

The need for this study and the appropriate subcontractor will be determined at the end of year one by the California Department of Fish and Game in consultation with the CALFED project manager.

Task 2: Human Health Risk Assessment and Bird Dietary Assessment of Mercury in the Sacramento Delta

Monitoring efforts in the Sacramento River Watershed Program, the Regional Monitoring Program in San Francisco Bay, and other programs have found mercury concentrations to be a potential human health concern in several popular sportfish species. This has resulted in fish advisories. CALFED is proposing several restoration efforts around the estuary which may increase methyl mercury production. These include creation of more shallow water habitat and beneficial reuse of mercury contaminated dredge material on the outside of delta island levees. It is vital to monitor and conclusively establish present fish tissue levels so that changes over time can be tracked and clear evidence obtained that the net effect of CALFED activities are to reduce fish tissue levels to concentrations below those impacting human or wildlife health

Subtask 2A: Assessment of Fish Tissue Mercury Concentrations and Potential Human Health Concerns

Lead Participant: San Francisco Estuary Institute

The first objective is to determine mercury concentrations in fish caught throughout the basin to better characterize the threat posed to human health by the consumption of fish from the Delta. The second objective is to establish statistically sound baseline data to evaluate the effect of mercury remediation and wetland restoration activity in the Basin. The third objective would be to have the California Office of Environmental Health Hazard Assessment and/or the California Department of Health Services (DHS) evaluate whether further consumption advisories are needed to protect human health.

The study will emphasize the collection of a variety of fish species at locations most intensively used by the California angling public. The California Department of Health Services and/or CA Office of Environmental Health Hazard Assessment will evaluate data collected to determine whether additional fish advisories are needed to protect human health and what the target mercury tissue concentration should be to fully protect human health. The latter will become the target for future CALFED restoration activities.

Subtask 2B: Assessment of Dietary Concentrations of Mercury to Fish-Eating Birds

Lead Participant: San Francisco Estuary Institute

An assessment of the ecological risks to wildlife associated with consumption of fish has not yet been performed for the Delta region. Piscivorous birds are one of the forms of wildlife most at risk from dietary concentrations of methyl mercury. Many fish-eating birds breed around the estuary and may be exposed to elevated dietary mercury concentrations. The objective of this study is to measure mercury tissue concentrations in fish species in the Delta that serve as bird prey items. These concentrations can be compared to dietary mercury concentrations in prey items that have been demonstrated to cause toxicity to birds. The results will be compared with the results of the egg surveys (Subtask 3A below) to determine whether field impairment can be demonstrated.

Task 3: Assessment of Mercury Hazards to Avian Reproduction in San Francisco Bay and the Sacramento-San Joaquin Delta

Human health concerns have been evaluated for San Francisco Bay and the Delta, resulting in advisories recommending limited consumption of fish from these areas due to mercury contamination. However, an assessment of the risks posed by mercury exposure to other top level consumers has not yet been performed and is needed to further evaluate ecological impacts in the region.

Subtask 3A: Field Assessment of Avian Mercury/Selenium Exposure in the Delta and Tributaries

Lead Participant: United States Fish and Wildlife Service

Mercury is dose-dependently transferred to the avian egg in organic form and has been shown to adversely affect avian reproductive success in the laboratory and the field. Adverse effects on hatchability, growth, embryo development and post-hatch success will be assessed based upon whole egg concentrations of mercury and/or selenium, utilizing comparisons with results of laboratory studies. Selenium is linked to a mercury evaluation because of the demonstrated synergistic and antagonist interactions of selenium and mercury in adult birds and their embryos and the bioaccumulative nature of selenium in the avian egg. Also, the Bay-Delta has significant sources of selenium and these may alter mercury bioavailability and toxicity. Eggs collected after 8 days of incubation will be assessed for avian developmental abnormalities and mercury and selenium tissue concentrations. The direct

assessment of viability has the advantage of demonstrating local bioavailability, as well as providing a direct means of assessing risk, through both determination of chemical concentration and embryo assessment. A variety of nesting aquatic species including rallids, waterfowl, shorebirds and colonial water birds will be collected and assessed. The field study will seek to assess 120 eggs/embryos per year, with at least four species represented in each quadrant of the delta and its tributaries in the spring of 1999 and 2000. Where possible, nest searches will be conducted in other areas of the Delta where high fish tissue concentrations (Subtask 2A) or elevated methyl mercury rates (Task 4) are measured.

Subtask 3B: Laboratory Assessment of Comparative Mercury Toxic Thresholds in Avian Species

Lead Participant: United States Fish and Wildlife Service

Cross-species comparisons are difficult because of the great amount of work required to carefully study free-living birds in nature or to establish a successfully breeding colony of captive birds suitable for controlled toxicity tests. Furthermore, many fish-eating birds take three or more years to reach reproductive age. This Subtask will assess the comparative toxicity of mercury to diverse species of birds, calibrate the toxicity to feeding study results obtained with mallards, and establish risk thresholds for egg residues of fish eating birds as well as other species. This will be accomplished by working directly with eggs and using egg injection techniques to dose embryos. To do this, investigators lead by Dr. Heinz will conduct a progression of studies, culminating in an assessment of the toxic thresholds of methyl mercury in the eggs of various fish-eating and other birds. This technique has the advantage of assessing many species to develop reliable toxicity thresholds. Meaningful results for multiple species are expected within the two year study period. The results can also be compared with the egg field results obtained in Subtask 3A above to assess the likely threat posed by mercury to the avian community.

Task 4: Assessment of Mercury Bioavailability and Flux Rates from Sediments throughout the Bay-Delta Watershed

Studies will be undertaken to determine the bioavailability of mercury in the different kinds of mercury-contaminated sediment present in tributary watersheds, as well as contaminated sediment once it is transported into the estuary. It is unknown whether mercury in sediments from the Coast Range, derived mainly from cinnabar, is equally bioavailable to mercury in sediments from the Sierra Nevada, derived from elemental mercury released during gold mining activities. The result of these studies should be definitive information on which tributary waterbodies are most important to remediate for both local and downstream mercury controls. The studies should also provide the first information on where the majority of mercury is being methylated in the Bay-Delta..

Two subtasks are proposed. Subtasks 4A (bioavailability studies) and 4B (flux studies) will use very similar flux measurement techniques and methodologies, at some common stations, but differ in the following important respects. Subtask 4A provides information on flux rates from mixtures of source and receiving sediments. Subtask 4B will intensely investigate flux in a subset of Delta receiving sediments, model the mercury riverine budget and determine temporal variations in flux rates from sediment that has not been mixed with source sediments. Personnel from the California Department of Fish and Game, Moss Landing Marine Labs and Texas A&M will collaborate in both studies to minimize study overlap and maximize efficiency in the lab and field. The study plan for each of the following tasks will undergo extensive scientific review before study commences.

Subtask 4A1: Field Studies-The Bioavailability of Mercury from Sediments of the Delta Watersheds

Lead Participants: California Department of Fish and Game,
San Jose State University Foundation @ Moss landing Marine Laboratories

The objectives of this subtask are to measure mercury and methyl mercury in sediments throughout the Delta Watershed to obtain preliminary estimates of methylation potential, and to measure the bioavailibility of mercury in Cache Creek and Mokelume River sediments in selected downstream habitats. The main hypothesis is "There is a

difference in bioavailability of mercury derived from sediments in different drainages". There will be an initial survey of 50 stations from throughout the Bay-Delta. Survey sites will be selected based upon historic data, habitat type, sedimentary type, mode of deposition, organic carbon, and other factors to be mutually identified with other investigators. This experiment will use methyl mercury/total mercury ratios in sediment to give a first order estimation of methylation potential which is a good proxy for bioavailability. Data collected from this survey will be used to characterize different habitat types and environmental conditions, as to their methylation potential. Subsequent mixing and flux experiments will be located in habitat types that encompass the range of methylation potential found during the initial survey.

Seventeen stations from differing habitats will be selected for measurement of methyl mercury flux, using results from the initial survey. Sediments from drainages found to contain relatively high levels of mercury, that are representative of mercury derived from cinnabar (Cache Creek), and mercury derived from elemental mercury (Mokelume River), will be transplanted to all seventeen different habitat types to determine if new environmental conditions stimulate different amounts of methyl mercury production in the two source sediments, as predicted from the initial survey. Three replicates will be analyzed in each habitat for each of two sampling periods. All methyl mercury flux rates will be determined in soft sediments using benthic flux chambers and/or diffusive flux methods utilizing interstitial pore water gradients. The flux chambers will be modeled after Gill et al. (in press), Mason et al., 1999, and Bloom et al., 1999 and will consist of a polycarbonate dome with a stirring mechanism inside to keep the water well mixed. All chamber components are ultra-trace metal cleaned to minimize mercury contamination. Flux rates are determined from changes in metal concentration over time within the flux chamber. The diffusive flux methodology involves extracting interstitial pore water from intact cores using ultra-trace metal clean protocols. Flux rates are determined from pore water gradients and diffusive models. Transplanting of sediment in the field is meant to complement concurrent laboratory investigations (Subtask 4A2) with similar sediment mixtures of 2 source sediments and 17 different receiving sediments.

Subtask 4A2: Laboratory Experiments-Methyl Mercury Flux as a Function of Sediment Source and Mixing

Lead Participant: Moss Landing Marine Laboratories

Laboratory studies will investigate mixing of Coast Range and Sierra Nevada Range sediments with those from the Delta to estimate changes in the rate of bioavailable mercury production resulting from downstream transport and mixing of natural sediments. These experiments will involve hybrid sediment types created by mixing source and receiving sediments from the habitats above. Methyl mercury flux rates from mixed sediments will be determined as above. Variables influencing flux rates will be investigated, such as redox conditions, mercury concentrations, temperature, overlying water velocity, amount of total and dissolved organic matter and microbial activity. The effect of certain benthic macrofauna on mercury flux will also be determined by adding organisms (such as *Potamocorbula amurensis*) directly to the incubated sediment samples. This study will be tightly coordinated with those in Subtask 4B where benthic fluxes will be measured using benthic flux chambers.

Subtask 4B: Mercury and Methyl Mercury Flux Rates

Lead Participant: Texas A&M University

Subtask 4B1: Quantification of the Sediment-Water Exchange (Flux) of Total Mercury and Methyl Mercury in the Estuarine and Delta Region of San Francisco Bay

This subtask is designed to provide detailed information on flux rates in receiving sediments. Mercury loads from tributary sources will be assessed in Task 1, however, information regarding the flux of mercury from sediment sources is absent or limited. The contribution of sediments to overall Bay-Delta mercury loading is expected to be significant as sediment loadings of methyl mercury have been found to be significant in Lavaca Bay, Texas (Gill et al. in press). The loadings from sediment need to be estimated and compared to loadings from the tributaries to determine their significance.

Determination of the sediment to water input flux of mercury and methyl mercury will be made at approximately 6 stations in the Estuarine and Delta Region of San Francisco Bay. Stations will be selected based on results from the

survey completed in Subtask 4A. Temporal variability at the six stations will be assessed by sampling three times a year. Flux rates will be determined using benthic flux chamber deployments and estimated from interstitial pore water gradients as described above (Gill et al., in press; Mason et al., 1999; Bloom et al., 1999).

Subtask 4B2: Determination of the Flux of Mercury and Methyl Mercury into (and out of) the San Francisco Bay Estuarine System from Riverine Sources and Estuarine Flushing

The objective of this subtask is to provide information on the relative significance and importance of the estuarine sediment input source proposed in Task 1. In order to scale the importance of the sediment input flux it is necessary to have information on other potentially important input sources. The other obvious source of methyl mercury to the upper estuary is via transport from upstream source regions.

Two estuarine transects will be conducted to capture extremes in riverine flow within the estuary and provide the maximum riverine source flux ranges. To obtain flux information, the estuary will be sampled across a salinity gradient for total, dissolved, and methyl mercury from Sacramento to the Carquinez Straights. The data obtained will be modeled using the mass balance geochemical approaches described in Flegal et al. (1991) and Wen et al. (1996) to quantify the riverine inflow, *in situ* production (or loss), and estuarine export flux of the mercury forms. This approach will provide an independent estimate to compare with the sediment-water fluxes determined in Subtask 4A.

Subtask 4B3: Determination of the Temporal Variation of Methyl Mercury Production at Selected "Hot Spots" in the Delta

It is now well documented that sulfate-reducing bacteria are the major organisms in sediments responsible for the production of methyl mercury from an inorganic mercury substrate (Gilmour et al., 1998). The activity and abundance of these organisms is expected to be related to several environmental parameters, particularly the availability of a food source, temperature, and redox conditions. Because these parameters can vary seasonally, it is anticipated that the production of methyl mercury in surficial sediments varies as well. Bloom et al (1999) observed that the methyl mercury content of surficial sediments and interstitial pore waters of a site in Lavaca Bay, TX varied seasonally. In early spring a dramatic increase in methyl mercury production occurred increasing the percentage of methyl mercury in sediments and also converting almost all of the interstitial pore fluids to methyl mercury. This subtask is designed to assess fine scale temporal variation in methyl mercury production over the course of a year, at one location.

Sampling will be conducted every 1.5 months for a period of 2 years to establish the methyl mercury production pattern at a key site in the Estuarine and Delta Region of San Francisco Bay. Sampling will consist of determining the methyl mercury to total mercury ratio at 6 depths (0, 1, 2, 3, 5, and 10 cm) in sediments and interstitial pore fluids. Sediments and interstitial pore fluids will be collected by sectioning and centrifuging a freshly collected intact core under anaerobic conditions following procedures described by Bloom et al. (1999). The site chosen for this study will be coordinated with other CALFED investigations and be one of the sites chosen for Subtask 4A.

Task 5: Mercury Sources, Bioaccumulation and Trophic Transfer in the Cache Creek Watershed

Subtask 5A: Identification of Mercury Sources (Hot Spots) and Bioavailability

Lead Participant: University of California, Davis

Objectives/Methods: Active and/or abandoned mining sites and total mercury "hot spots" within the Cache Creek Watershed will be identified using an existing Geographical Information System mercury database for California (developed by the U.C. Davis Mercury Group) and in conjunction with the California Division of Mines and Geology (R. Churchill – see below). At these sites, mercury sources that have the potential to be transported to Cache Creek and beyond will be characterized, quantified and the most abundant chemical forms of mercury will be speciated. The UC Davis Mercury Group will rely on collaborations with the U.S.G.S. team and others to obtain these data. Lakes/streams that have the potential to carry mercury from these sources (e.g. Clear Lake, Indian Valley Reservoir, Davis Creek Reservoir, Harley Gulch, Sulfur Creek, Bear Creek, Grizzley Creek) will be

investigated for loading from the different mercury sources. U.S.G.S. will be determining mass loading and key inorganic and organic mercury fractionation. Once the primary forms of mercury have been identified, selected benchtop studies (microcosm experiments using the methods of Mack et al. 1997) will be used to quantify the potential for each mine source to produce bioavailable forms of mercury (e.g. methyl mercury) under a variety of in-stream/down-stream environmental conditions. The primary objective of this work will be to characterize the most important forms of initial source mercury that promote mercury methylation, bioaccumulation, and transfer to higher trophic levels (see Task 5B). This will direct future remedial work to the most appropriate and highly localized sites.

Subtask 5B: Characterization of Mercury Bioaccumulation and Trophic Transfer

Lead Participant: University of California, Davis

Objectives/Methods: To develop a predictive relationship between mercury chemistry in water and sediments from various sources (see Subtask 5A above) with that in biota (e.g. aquatic invertebrates and fishes), data will be collected to characterize environmental mercury chemistry and compare with mercury accumulations in invertebrates and small fishes (used as key bioindicators, Slotton et al. 1997a, b, c, 1998), both spatially and temporally within the Cache Creek Watershed, together with additional large fish collections. Biotic data will be compared with the various mercury sources identified above. This work will (1) document the temporal and spatial variability in mercury biocontamination within the watershed, (2) provide linkages between sediment/water mercury and biotic mercury and between useful bioindicators and higher trophic levels, (3) provide mercury data to USF&W to address wildlife concerns (small fish) and OEHHA human health concerns (large fish), and (4) establish baseline seasonal biotic mercury data for the watershed so that changes in mercury bioaccumulation may be readily assessed once remediation is undertaken. These data are essential to quantify the amount of load reduction needed from various sources and for remediation feedback. OEHHA will evaluate the data to determine if health advisories should be issued.

Subtask 5C: Assessment of the Feasibility of Remediation of Mercury Mine Sources in the Cache Creek Watershed

Lead Participant: California Department of Conservation, Division of Mines and Geology

Sulfur Creek and Harley Gulch have been identified as major sources of total and bioavailable mercury. Site remediation feasibility studies should be undertaken in these areas to identify the major sources of the bioavailable mercury and the most practical, cost-effective control methods to minimize off site mercury movement. There may be as many as 12 former mine sites that need preliminary assessment to document the potential for remediating mercury runoff. The initial assessment would include visiting all the mine sites, drawing detailed site maps, collecting samples of waste pile material and soil for mercury content determinations, estimating the potential for offsite mercury transport, and estimating approximate costs for remediation. The Department of Conservation, Division of Mines and Geology will conduct all the initial assessments. Later assessments would involve hiring mine remediation experts to conduct a detailed evaluation of the important sites identified in the initial assessment and estimate a more precise cost for remediating the mercury offsite transport. Control efforts for evaluation may include runoff and waste material isolation studies, natural revegetation, waste rock removal and infiltration evaluations. This task will be funded in year 2 contingent on findings from the U.S. Geological Survey (Subtask 1C above) that indicate that mercury loadings from this area are significant relative to loadings from other areas.

Task 6: Project Management and Logistical Coordination

The proposed project will be managed by Mark Stephenson and Max Puckett of the California Department of Fish and Game (CDFG) through the San Jose State University Foundation (SJSUF). The CDFG has a standing relationship with SJSUF and Mr. Stephenson has served as principal investigator at Moss Landing Marine Laboratories (MLML) through SJSUF on over 30 projects. Dr. Kenneth Coale, Acting Director of MLML, is participating in this project as a researcher and will be a co-principal investigator in managing the project with CDFG. An experienced team of researchers from a number of other agencies and universities will participate in implementation and completion of the individual tasks described above. Coordination, oversight and contracting of this team of investigators will be the principal management task for CDFG and SJSUF.

Subtask 6A: Administrative Management

Lead Participant: California Department of Fish and Game

This includes the day to day work involved in preparing, processing, and managing the numerous subcontracts, as well as the reimbursable contract, for the project. It also includes all associated administrative management duties such as invoicing, purchasing, personnel, and accounting. The budget for this subtask includes the estimated overhead costs for the pass-through subcontracts, as well as the tasks described herein.

Subtask 6B: Project Reporting and Coordinating

Lead Participant: California Department of Fish and Game

The work performed in this subtask includes the preparation and submission of Quarterly Progress Reports to the CALFED contract manager; the planning and conducting of quarterly status meetings with all project investigators to review progress and issues from the previous quarter; the preparation and submission of the project Final Report; and the preparation and submission of other deliverable products as specified.

Subtask 6C: Data Management and QA/QC

Lead Participant: California Department of Fish and Game

The work performed in this subtask includes duties associated with quality assurance and quality control review and participant reporting of data (reviewing the data for compliance with Quality Assurance Project Plan specifications). This subtask also includes the development and assurance of standardized reporting formats for all participants for data and for reports, as well as for standardized reporting of field sampling station information, such as latitude and longitude, database headings, station numbering and naming, etc. A QAPP will be produced based upon the Sacramento River Watershed Program's QAPP.

Subtask 6D: Public and Agency Outreach

Lead Participant: California Department of Fish and Game/Sacramento River Watershed Program

The duties of this subtask are to ensure the timely and proper dissemination of project information to a wide variety of interest groups. This would include duties such as presentations to scientific and agency peers, seminars and workshops for the interested or affected public, preparation and dissemination of news releases or informational brochures, and other outreach efforts as necessary. The Sacramento River Watershed Program will conduct much of this part of the program as a cost share. It will include information in newsletters, present relevant information at its workshops, committee meetings, and public outreach meetings. In addition, the project will sponsor a seminar series at U.C. Davis for the northern California mercury community where 8-10 nationally/internationally recognized mercury experts will be brought in to help educate those interested in the latest developments in mercury research and monitoring. Most of the investigators in this project will also give talks to the public and to scientific peers.

Subtask 6E: External Scientific Review and Oversight

Lead Participant: California Department of Fish and Game

An external scientific review and oversight committee consisting of 3-5 internationally/nationally recognized mercury cycling experts with no financial connection to this project will be formed to critique and provide suggestions for improvement. Input from the scientific review and oversight committee would be sought prior to the commencement of any data collection, at midterm, and at the end of the project. All recommendations will be collated and distributed to the Cache Creek Mercury Group, the Sacramento Watershed Toxics Subcommittee and the CALFED project manager along with the California Department of Fish and Game's response to the review

comments/criticisms. The scientific review committee will work closely with the Cache Creek Mercury Group in obtaining this groups review on all activities planned for Cache Creek. This subtask includes the duties associated with creating the committee by invitation, taking care of all logistical considerations of planning the actual meetings (travel arrangements, room reservations, agenda packets, audiovisual materials, etc.), assisting in the conducting of the meetings, and preparing and distributing meeting summaries.

LOCATION AND/OR GEOGRAPHIC BOUNDARIES OF THE PROJECT

The area encompasses the entire Sacramento/San Joaquin River Watershed downstream to the Carquinez Straights.

ECOLOGICAL OBJECTIVES AND RELATED BENEFITS

A. Primary ecological/biological objectives of project:

The objective of the project is to provide information that will lead to a reduction of mercury in resident fish tissues to levels that are not harmful to humans and wildlife.

B. Scientific hypothesis/question to be evaluated by project:

CALFED and other management actions will lead to reductions in mercury fish tissue to levels that are not harmful to humans and wildlife.

C. Relation of this project to other current and previously funded projects:

There are a number of ongoing or recently completed mercury studies in the Sacramento watershed and/or Delta-Estuary. This project will be closely coordinated with each to insure that no duplication of effort occurs. Coordination efforts with each project are briefly outlined below. First, the San Francisco Estuary Institute (SFEI) in cooperation with the Office of Enviromental Health Hazard Assessment (OEHHA), is managing fish tissue studies in San Francisco Bay for the San Francisco Regional Board, in the Sacramento Watershed for the Sacramento Watershed Program, and in the San Joaquin Basin and South Delta for DeltaKeeper. The purpose of all three studies is to determine whether mercury concentrations in fish tissue pose a human health problem. SFEI, in coordination with OEHHA and DHS, will supervise these studies (Task 2). The result will be the first comprehensive evaluation of mercury concentrations in fish across the entire Bay-Delta system.

Second, there is an ongoing long-term Remedial Investigation/Feasibility Study (funded by USEPA Superfund) being conducted by T.H. Suchanek and P.J. Richerson (1992-present) at the Sulphur Bank Mercury Mine site at Clear Lake. The purpose of these studies is to determine how mercury is being moved off the mine site and into Clear Lake, and the subsequent dynamics of mercury bioaccumulation in the Clear Lake aquatic food chain. The ultimate objective of the work is to determine the most cost-effective way to remediate the mine site and remove the mercury fish advisories from Clear Lake. D.G. Slotton has been leading a mercury bioaccumulation and loading research program in the Davis Creek watershed (tributary to Cache Creek) since 1985 and has also conducted a variety of additional mercury loading and bioassessment studies throughout the Cache Creek study region that form the preliminary basis for some of the proposed work. Drs. Suchanek and Slotton (U.C. Davis) are also the recent recepients of an ongoing CALFED grant (1998-2001) to evaluate the importance of flooded Delta Islands in the production of methyl mercury in the estuary. Both investigators will be responsible for conducting the Cache Creek mine remediation source studies (Task 5A) and determining mercury bioaccumulation in the Cache Creek aquatic food chain (Task 5B). They will also be actively involved in the methylation studies in the estuary (Task 4).

Third, the U.S. Geological Survey, Larry Walker Associates, and Central Valley Regional Board recently completed independent mercury mass load studies in the Sacramento watershed. Larry Walker Associates, through the Sacramento Watershed Program, will continue to conduct mercury loading studies in the Sacramento Watershed. This work will be done in close cooperation with the designated action. The U.S. Geological Survey will be the lead on mercury mass loading studies in the Cache Creek drainage (Task 1). The Central Valley Regional Board will conduct loading studies in the Cosumnes, Mokelumne, and San Joaquin Basins and in the special storm event studies in Cache Creek (Task 1).

Finally, the Department of Fish and Game has recently been funded by CALFED to study reuse of sediments in the Delta. Although a project sampling strategy has not been finalized, it is expected that the proposed project can be closely coordinated and possibly linked with the Department Fish and Game's currently funded project, especially since any reuse of Delta sediments may release methyl mercury into the overlying waters.

MONITORING AND DATA COLLECTION METHODOLOGY

A Quality Assurance Project Plan will be prepared that will detail monitoring and collection methodologies. This project will take advantage of the existing QAPP from the Sacramento River Watershed Program and modify it to meet the project's needs. Standard nationally recognized methods will be utilized where possible. However the nature of some projects will require the use of emerging technologies and performance based methods. The methodologies for mercury and methyl mercury analysis will be identical to or comparable to Frontier Geoscience's methodology. Frontier Geoscience has been a pioneer in developing mercury and methyl mercury methods and its employees have been in the forefront of mercury analytical chemistry by sponsoring international intercalibrations and being the principal authors of many of the EPA approved methodologies. At the onset of the research, intercalibrations will take place to insure all methodologies are comparable. In addition, all the labs will agree to same high level of QA/QC. See Table 1 (attached) for a summary of ecological/biological objectives, associated hypotheses, and monitoring parameters and approaches to be used. Sediment variability will be evaluated in Task 4 so that representative samples can be taken from each site.

Peer review will be used to address outstanding issues, including methodological issues, and will occur in at least three ways. As mentioned in Subtask 6E, an Oversight Committee of nationally recognized mercury experts (three to five individuals) will be assembled to review proposed projects prior to any data collection, at midterm, and at the end of the project. The Cache Creek Mercury Group will also be involved in review of studies in the Cache Creek area. At each stage their comments will be collated, summarized, incorporated into project plans and distributed for public review. Second, periodic program reports will be prepared and distributed to the Cache Creek Mercury Group, the Toxic subcommittee of the Sacramento Watershed Program and the stakeholders of the CALFED Water Quality Common Program for review and comment. Representatives of the Oversight Committee would be available to review the program and answer public comments at a regularly scheduled meeting of the Cache Creek Mercury Group. Finally, draft final reports will be widely distributed for review by both local and national mercury experts and the lay public before being finalized.

TECHNICAL FEASIBILITY AND TIMING

A. Explain which alternatives were evaluated, and why were they not selected?

An alternative to doing the work outlined above would be to only use existing information (summarized by Foe and Croyle, 1998, Larry Walker and Associates, 1997; Roth *et al.*, 1998) regarding inorganic mercury loads and sources as the basis for commencing load reductions. However this alternative does not provide sufficient data for determination of baseline conditions from all likely important sources nor does it consider bioavailability of the material. Also, there remain significant uncertainties regarding the potential bioavailability of source materials and magnitude of loads of total and methyl mercury . Another alternative is taking no action, but this leaves no means for evaluating current impacts of mercury on the Bay/Delta system or for judging the effectiveness of any wildlife protection efforts or remediation activities implemented in the future. This clearly would not meet the objectives of the CALFED Program.

B. What CEQA and NEPA documents have or will be prepared for the project?

No CEQA or NEPA documentation will be needed.

C. Explain what permits or agreements need to be in place to proceed, and explain the current status of each permit or agreement. Explain any other constraints that could impact the schedule and implementability of the project.

The mercury mines and geothermal springs in Harley Gulch and Sulfur Creek are on private property. Property owners will need to be identified and their permission secured in order to undertake the mine remediation feasibility studies (Task 5). Regional Board, Fish and Game, and Department of Conservation staff will be responsible for securing permission from all local landowners.

Other constraints that might impede the implementability of the project would be physical access to sample collection sites, particularly in the Cache Creek canyon and possibly in the Sulfur Creek/Bear Creek area at high flow conditions. Also, permission will be required for collection of water samples at some sites on private land.

D. Identify the nature and approach to resolving other outstanding implementation issues.

There are no other outstanding implementation issues.

COST AND COST-SHARING

A. Budgets: See Table 2 and Table 3 (attached).

B. Other funding commitments, status of commitments, source, and any cost-sharing requirements.

Cooperating agency	cash	status	In kind	total
USGS State-Federal Cooperative Hydrology Program	$227,000	Tentative approval	$0	$227,000
USGS National Research Program, Water Resources Division	$ 0	Tentative approval	$200,000	$200,000
California Dept. of Conservation – Abandoned Mines Unit	$ 16,000	Tentative approval	$20,000	$36,000
Fairfield-Suisun Sewer District	$ 9,000	Tentative approval	$2,000	$11,000
Central Contra Costa Sanitation District	$ 6,000	Tentative approval	$2,000	$8,000
Sacramento River Watershed Program		Tentative approval	$260,000	$260,000
California Dept. of Fish and Game	$ 0	Tentative approval	$10,000	$10,000
Yolo County	$ 30,000	possible	$20,000	$50,000
Homestake Mining Company	$ 0	Tentative approval	$50,000	$50,000
Other local or state agencies (to be determined)	$ 80,000	speculative	$0	$80,000
Totals	$406,000		$304,000	$710,000

NOTE: The USGS must receive non-Federal funds to be eligible for matching with funds from their State-Federal Coop Program. Therefore the $320,000 budgeted for Task 3A will need to be all state money from CALFED.

In addition, the following in-kind or matching fund contributions are tentatively planned for this project, if funded:

- The Central Valley Regional Water Quality Control Board will tentatively encumber $50,000 of 1998-99 salary-savings money to be contributed towards matching funds; and
- The California Department of Fish and Game (Moss Landing Marine Laboratory) will tentatively allocate approximately $50,000 of in-kind time.

- The Central Valley Regional Water Quality Control Board will allocate $50,000 of Toxic Substances Monitoring Program funds to the Fish related studies.
- The Sacramento River Watershed Program will provide a cost share by analyzing total and possibly methyl mercury in the Sacramento River, and provide funding for the Cache Creek Mercury Group moderator, and will provide assistance in outreach. The amounts committed to this cost share are: $30,000 for Cache Creek Coordinator; $45,000 for water monitoring; $35,000 for fish monitoring; and $180,000 for stakeholder involvement.

C. Identify the potential to incrementally fund/implement the proposed scope of work.

Most studies need to be conducted concurrently except for those that are contingent upon results of year one studies.

LOCAL IMPACTS, SUPPORT, AND INVOLVEMENT

A. Is the county (ies) where the project is located aware of the project? Have they been notified in writing of the project? Are they supportive of the project?

The Directors of Public Works for Yolo, Lake, Sacramento, Colusa, Solano and San Joaquin Counties all received draft copies of the proposal for review. Each was asked to call if they had concerns. No calls were received.

B. Which local groups, including environmental groups, conservancies, CRMP's, or other interested organizations are aware of the project? Which are supportive of the project? Which oppose the project?

SFEI, San Francisco BayKeeper and its sister organization DeltaKeeper, the Cache Creek Mercury Group and the Toxics Subcommittee of the Sacramento Watershed Program have all been notified that a mercury proposal is being prepared for CALFED. SFEI, DeltaKeeper and representatives of the Toxics Subcommittee have all indicated their support. We suspect the Cache Creek Mercury Group will also support the project as many of the ideas in the proposal were advanced by the group in their mercury write up to the CALFED Water Quality Common Program. However, no general meeting of the group has been held so their formal approval has not yet been obtained.

C. Are adjacent or affected landowners, facility owners, and facility operators aware of the project? Are they supportive? Are any opposed to the project?

No local landowners are yet aware of the project.

D. Does your project have a plan for public outreach to the groups listed above or to others who may be affected by the project?

Yes, public outreach will occur through mail outs and meetings of the Cache Creek Mercury Group, the various subcommittees of the Sacramento Watershed Program, Cache Creek Mercury Group (stakeholders), and the CALFED Water Quality Common Program.

E. Identify any potential third party impacts.

No third party impacts have been identified.

COMPATABILITY WITH NON-ECOSYSTEM OBJECTIVES

Explain whether the project also provides benefits for or conflicts with other CALFED objectives, including water quality, water supply reliability, and levee system integrity.

This project will provide information that will help guide CALFED in funding restoration projects that will enhance water quality by lowering mercury loading into the Bay/Delta system.

Appendix

- Attachment One: Project Organization and Applicant's Qualifications
- Attachment Two: List of references cited in the proposal
- TABLE 1. Summary of ecological/biological objectives, associated hypotheses, and monitoring parameters and approaches
- TABLE 2. Total Budget: CALFED Funds Only
- TABLE 3. Quarterly Budget

ATTACHMENT ONE: PROJECT ORGANIZATION AND APPLICANT'S QUALIFICATIONS

A. Describe the planned organization and qualifications of the staff and other resources to be used in implementing the project.

The proposed project will be managed by Mark Stephenson and Max Puckett of the California Department of Fish and Game through San Jose State University Foundation. The Department has a standing relationship with San Jose State University Foundation and Mark Stephenson has served as principal investigator at San Jose State University Foundation (SJSUF) at Moss Landing Marine Laboratories on over 10 projects. Dr. Kenneth Coale, Director of Moss Landing Marine Labs, is participating in this project as a researcher and will be a co-principal investigator in managing the project with the Department of Fish and Game. Mark Stephenson and Max Puckett are currently managing the monitoring part of the State Water Resources Control Boards Bay Protection and Toxic Cleanup Program which has a very similar funding level and complexity of multiple investigators in collaboration with SJSUF and other institutions. Coordination, oversight and contracting of the team of investigators participating in this project will be the principal management task for the Department and the SJSUF.

B. Use of/limitations to competitive bidding:

Competitive bidding was not used for selection of participants. Participants were selected because in their respective fields of expertise they were the most knowledgeable and respected in the country.

C. Applicant's Qualifications

Main contractor:

CALIFORNIA DEPARTMENT OF FISH AND GAME/ MOSS LANDING MARINE LABORATORIES

Mark Stephenson is the Director of the California Department of Fish and Game's Marine Pollution Study Group and is a Principal Investigator on several research projects at San Jose State University (SJSU). Mr. Stephenson's facility is located at Moss Landing Marine Labs, a laboratory administered through SJSU, and he has been conducting joint research projects with Moss Landing Marine Lab faculty since 1977. He has been assessing mercury contamination in the marine environment as part of the California State Mussel Watch program for 22 years. In the last 10 years, Mr. Stephenson has worked on mercury contamination issues at the New Almaden Mine, New Idrea Mine, and Walker Creek Mine. He has participated in mercury loading studies with the Sacramento River Watershed Program, the California Department of Water Resources, and the Central Valley Regional Water Quality Control Board in Sacramento. Mr. Stephenson has provided leadership and overall management for several multi-million dollar, multi-investigator projects, including most recently the Bay Protection and Toxic Cleanup Program. The Department of Fish and Game has the laboratory capability of analyzing mercury in tissue, sediment, and in water. The laboratory has the only operational low-level mercury water analysis system in the state. **Max Puckett** is an Environmental Specialist for the California Department of Fish and Game, and serves as the Director of the Granite Canyon Marine Pollution Studies Laboratory. In this capacity, Mr. Puckett has served as the day-to-day technical and administrative manager for numerous large-scale, long-term, multi-agency cooperative scientific projects, including most notably the Bay Protection and Toxic Cleanup Program. In the last six years, Mr. Puckett's management duties in the Bay Protection and Toxic Cleanup Program have entailed the preparation and oversight of nearly 50 contracts and amendments totaling over ten million dollars for nearly 15 different agencies and organizations. Mr. Puckett has over 20 years of experience in conducting as well as managing environmental studies, specializing in pollution studies and their impacts on natural resources management. Mr. Puckett has a Master's Degree in Natural Resources Management/Fisheries from Humboldt State University (Arcata, CA), as well as a Bachelor's Degree from the University of Florida (Gainesville, FL) in Zoology/Environmental Studies. **Dr. Kenneth Coale** is a biogeochemist with 25 years experience in trace metal biogeochemistry and currently serves as the Acting Director of Moss Landing Marine Laboratories. For the last 10 years, Dr. Coale has received funding from the National Science Foundation and the Office of Naval Research to study the processes which control the flux of toxic metals and nutrients between the sediments and overlying waters of the LA/Long Beach, San Francisco Bay, and continental coastal margin systems using benthic flux chambers and sediment porewater modeling. Other

interests include a) Trace element biogeochemistry in the California Current and North and South Pacific Oceans. b) The use of naturally occurring U/Th series radionuclides in the study of biologically mediated chemical scavenging, removal and recycling processes. c) ^{226}Ra:^{210}Pb disequilibria to date rockfish otoliths. d) Trace metal speciation and the effect of metal speciation on trace metal limitation of phytoplankton productivity in open ocean and coastal systems. e) The distribution and cycling of trace metals in lacustrine systems. f) Trace metal cycling and removal in hydrothermal plumes. g) The role of continental margins in supplying trace metals to the ocean's interior. h) Development of analytical methods for the determination of trace metals in natural waters. i) The use of excess ^{210}Pb in dating marine sediments. He has served as a panelest on the National Science Foundation's Chemical Oceanography review committee, is an Associate Editor of Marine Chemistry, Special Editor of the most recent issue of Deep-Sea Research, Volume II, has participated on over 50 oceanographic cruises, and has over 40 peer reviewed publications on trace metals in marine and lacustrian environments. . **Russell Fairey** has served as a project manager and environmental scientist at Moss Landing Marine Laboratories since 1992. His areas of expertise include trace metal flux from marine sediments, marine sediment pollution and fish tissue contamination, with peer reviewed publications in each of these areas. He has played an active technical and management role in numerous federal, state and local, multi-agency projects including, EPA's Environmental Monitoring and Assessment Program, California's Bay Protection and Toxic Cleanup Program, and San Francisco Bay's Regional Monitoring Program. Project funds managed for Moss Landing Marine Laboratories over the last eight years exceed $3.6 million. Current research includes development of sediment quality guidelines and is highlighted by his participation in the international Science Advisory Group on Sediment Quality Assessment.

Participants:

U.S. FISH AND WILDLIFE SERVICE

Dr. Steven Schwarzbach is a wildlife toxicologist and serves as chief of the Environmental Contaminants Division in the Sacramento field office. He has conducted numerous field and laboratory studies of environmental contaminants and specializes in avian reproductive toxicology. He has published a review of mercury toxicity to birds, and has directed numerous avian reproductive field studies in the Tulare Basin, Klamath Basin, San Joaquin Valley, Sacramento Valley, Cache Creek, and the tidal marshes of San Francisco Bay. **Dr. Joseph Skorupa** is a senior biologist within the environmental contaminants division, and has conducted numerous field studies on the reproductive effects of selenium in birds as well as publishing several reviews on the toxicity of selenium to biota. **Thomas Maurer** serves as the branch chief of the environmental contaminants division and has over 17 years experience in conducting environmental contaminant field investigations, including 10 years in California ecosytems impacted by agricultural drain water. Over the last 25 years **Drs. Hoffman and Heinz** have published together or separately over 30 papers on the toxicity of mercury and/or selenium to birds in controlled feeding studies. Recently they demonstrated that mercury and selenium act synergistically to harm mallard reproduction when combined together in the diet (Heinz and Hoffman, 1998). Dr. Heinz conducted a three generation study of mallards in the 1970s which is now used as the baseline toxicity study for all bird species. Dr. Hoffman is an avian terratologist. Heinz and Hoffman are uniquely qualified to extend their research into the relative toxicity of mercury and mercury with selenium in mallards to other avian species

U.S. GEOLOGICAL SURVEY

Dr. Charles Alpers is a Research Chemist with the U.S. Geological Survey, Water Resources Division, California District Office in Sacramento. He received a Ph.D. in Geology from the University of California, Berkeley in 1986, and was a National Research Council Post-Doctoral Research Associate with the USGS in Menlo Park, Calif. from 1987-89. Since 1991, he has been the project chief for several geochemical and hydrogeologic studies of metal transport involving mine drainages, their environmental impacts, and their remediation. **Dr. Domagalski** is a Supervisory Hydrologist with the U.S. Geological Survey, Water Resources Division, California District Office in Sacramento. He received a Ph.D. from Johns Hopkins University in 1988). From 1988-93, he worked on pesticide chemistry, fate, and transports for several USGS projects located in the Central Valley and San Francisco Bay. Since 1993 he has managed the USGS National Water-Quality Assessment (NAWQA) project in the Sacramento River Basin, including studies of mercury and methyl mercury concentrations. **Drs. Taylor and Roth** are both Research Chemists with the U.S. Geological Survey, Water Resources Division, National Research Program in

Boulder, Colorado. They have extensive experience in mercury analysis and its application to environmental problems. Since 1996, they have participated in the USGS study of metal transport in the Sacramento River. **Dr. Krabbenhoft** is a Research Hydrologist with the USGS, Water Resources Division, Wisconsin District Office in Madison. He is an internationally recognized expert on mercury geochemistry, and has participated in numerous studies of mercury fate and transport in California, Florida, Wisconsin, and elsewhere

UNIVERSITY OF CALIFORNIA, DAVIS

Dr. Darell Slotton has directed applied research projects addressing heavy metal contamination and bioaccumulation issues in California aquatic ecosystems for 15 years, with a primary focus on mercury. He has led investigations of copper, zinc, and cadmium contamination at Iron Mountain Mine and Camanche Reservoir, where sediment resuspension and metals transport, solubility, and bioavailability were investigated in a multi-year project. Since 1985, he has run a mercury biogeochemistry monitoring and research program at Davis Creek Reservoir and a mercury analytical laboratory at UC Davis. Between 1993 and 1998, Dr. Slotton led a research program throughout the foothill gold mining region of the Sierra Nevada, primarily focusing on benthic invertebrates as proxies for relative bioavailable mercury concentrations and loading. He conducted an intensive, multi-year study of mercury mass loading, bioaccumulation, and remedial options at the Mt. Diablo Mercury Mine and Marsh Creek watershed. Current projects include mercury bioassessment studies in both lower Putah Creek and its upper watershed, and a large Delta study of mercury bioaccumulation and methylation (with Dr. Suchanek). Slotton has led 5 different mercury studies (several ongoing) throughout the Cache Creek watershed below Clear Lake extending to the Settling Basin. He has also been a part of the Clear Lake Superfund Mercury Project (see below) since its inception. **Dr. Thomas Suchanek** is a Research Ecologist and Director of the U.C. Davis – Clear Lake Environmental Research Center (UCD-CLERC). He has led multi-disciplinary and inter-disciplinary ecosystem projects for over 18 years and has focused on the impacts of mercury on California resources since 1991. All of these programs have involved multiple investigators from many disciplines and several have involved multi-million dollar budgets. Dr. Suchanek is also western regional director of the National Institute for Global Environmental Change (a Department of Energy sponsored program) and he administers a $1.2M/yr program dealing with anthropogenic impacts on ecological systems. Dr. Suchanek is also Principle Investigator for an ongoing inter-disciplinary project (which is in its final phases) studying the biogeochemistry and ecosystem impacts of mercury contamination from the Sulphur Bank Mercury Mine Superfund Site on the aquatic ecosystem of Clear Lake, CA. Numerous reports and publications dealing with a variety of mercury issues have resulted from these and related studies and the final product will be a set of effective remedial recommendations (to the U.S.E.P.A) targeted to lower mercury levels in edible fishes within Clear Lake. Dr. Suchanek is also lead P.I., with Dr. Slotton, on an ongoing CALFED funded project to evaluate the effects of wetland restoration on the production of methyl mercury in the San Francisco Bay-Delta Estuary. **Dr. Douglas Nelson**, Professor of Microbiology, is an internationally recognized expert on microbiology of the sulfur cycle. Both oxidative and reductive portions of the cycle are included in this multifaceted program which encompasses field research (deep-sea sulfide-rich vents and seeps; sediments of Clear Lake, CA; evaporation ponds of the San Joaquin drainage) and laboratory research (ecology and physiology of pure cultures, mixed cultures and microcosms). Funding sources include NSF, NOAA-National Undersea Research Program, Mineral Management Services of US Department of Interior and UC Salinity Drainage Program. Since 1992, he has been involved in US EPA sponsored studies of mercury methylation in Clear Lake sediments. Important findings there included: (1) a demonstration that sulfate-reducing bacteria, previously believed by others to be primary methylators of mercury in anoxic sediments, perform roughly 25% of the total sediment methylation (2) a demonstration that the vast majority of sediment inorganic mercury is not available for methylation.

TEXAS A & M, GALVESTON

Dr. Gary A. Gill is an Associate Professor of Oceanography at Texas A&M University in Galveston. Dr. Gill's area of research specalization is in the biogeochemistry of trace elements in natural waters, with particular experience and interest in environmental and analytical studies concerning mercury. Dr. Gill has more than 20 years of experience with a wide variety of environmental mercury studies and the analytical determination of ultra-trace levels of mercury in the environment. He has more than 20 peer-reviewed publications related to the analytical

chemistry or biogeochemical cycling of mercury in the environment and has presented numerous presentations involving environmental mercury studies at national and international scientific meetings. Dr. Gill has most recently worked on environmental mercury problems at an EPA Superfund site in Lavaca Bay, Texas and has also has conducted mercury research in South Florida for the Florida Department of Environmental Protection to address mercury problems associated with the Everglades.

CENTRAL VALLEY REGIONAL WATER QUALITY CONTROL BOARD

Dr. Chris foe has worked for the regional board in a special studies section since 1987. Between 1993-95 he conducted an inorganic mercury load study to the bay-delta estuary and determined that cache creek in the coastal range was a major source of estuarine mercury. He is the author of the regional board's Bay Protection and Toxic Hot Spot Cleanup Plan for mercury.

SAN FRANCISCO ESTUARY INSTITUTE

Dr. Jay Davis is an environmental scientist with the San Francisco Estuary Institute. Dr. Davis received his Ph.D. in Ecology at the University of California, Davis in 1997. His dissertation research was on the effects of organochlorines in the double-crested cormorant, a fish-eating bird species, in San Francisco Bay. Dr. Davis has worked on contaminant issues in the San Francisco Estuary since 1986. Dr. Davis worked for the Aquatic Habitat Institute from 1986 to 1992. During this period he co-authored several Institute reports, including Status and Trends Reports on Pollutants and Dredging and Waterway Modification for the San Francisco Estuary Project. He joined the staff of SFEI in 1995. Dr. Davis is part of a team that manages the Regional Monitoring Program for the San Francisco Estuary, and is managing three projects examining contaminants of human health concern in fish from the Bay, the Sacramento River watershed, and the Delta.

CA OFFICE OF ENVIRONMENTAL HEALTH AND HAZARDS ASSESSMENT

Dr. Robert Brodberg has been intimately involved with many sports fish health risk assessments. Most recently he has been the principal advisor on health risks for the San Francisco Bay and Bay Delta health risk studies targeting sports fishing..

CA DEPARTMENT OF HEALTH SERVICES

Dr. Smith is Chief of the Exposure and Assessment and Molecular Epidemiology Section at DHS environmental Health Investigations Branch. He holds a doctoral degree in epidemiology, with an emphasis on epidemiological methods. He has a wide range of experience in the design and analysis of environmental epidemiology investigations including the health impacts of contaminated fish. In his role as Chief, he has been responsible for the scientific conduct of over 30 environmental epidemiology studies. Dr. Smith is also a member of the Santa Monica Bay Restoration Project Seafood Task Force. He has also provided technical assistance in the development of 2 sports fish consumption surveys, the Santa Monica Bay Consumption Survey and the San Francisco Bay Seafood Consumption Study.

CALIFORNIA DEPARTMENT OF CONSERVATION, DIVISION OF MINES & GEOLOGY

Dr. Ron Churchill is a Senior Geologist, Specialist, with the California Department of Conservation, Division of Mines and Geology (DMG), and a Registered Geologist in California. He received a Ph.D. in Geology (Mineral Deposits) from the University of Minnesota, Minneapolis in 1980. Dr. Churchill has nine years of industry

experience in precious, strategic and energy minerals, with exploration and research projects in the western U.S. and Mexico involving detailed geochemical studies of mine sites. Dr. Churchill has been in charge of the DMG geochemistry lab for the last ten years. His responsibilities at DMG include: (1) geochemistry and mineralogy support for SMARA Mineral Land Classification Projects; and (2) mineral hazards studies for mercury, radon and asbestos. Current mineral hazard activities by Dr. Churchill include the compilation of a mercury mine and prospect database for use in environmental and hazard assessment of mercury sites in California, and providing geologic support for El Dorado County Asbestos Task Force.

ATTACHMENT TWO: LITERATURE CITED IN THE PROPOSAL

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Table 1. Summary of Ecological/biological objectives, associated *hypotheses*, and *monitoring parameters* and approaches

*Hypotheses/questions to evaluate for specific Tasks above:		
Task 1A&B:		
1) What is the major source of estuarine methyl mercury input from the mainstem rivers or *in situ* production within the estuary; and		
2) What is the methylation potential of inorganic mercury from each source once in the Estuary?		
Task 1C:		
1) Large annual mercury loads from Cache Creek and the Yolo Bypass are major contributors to elevated fish tissue Hg levels in the Bay/Delta;		
2) Reducing mercury loads to the Bay/Delta from Cache Creek and the Yolo Bypass will lead to an eventual reduction in mercury concentrations in fish tissue;		
3) The mercury loads in Cache Creek and the Yolo Bypass come from different sources in the watershed depending on the climatic conditions (Foe and Croyle, 1998);		
4) Better quantification of mercury and methyl-mercury loads including natural vs. anthropogenic sources are essential to effective and cost-efficient remediation and/or load reduction efforts;		
5) Different forms of mercury become methylated and demethylated at different rates depending on environmental conditions, therefore quantitative characterization of mercury forms is needed to allow prediction of the benefits of mercury load reduction; and		
Task 1D:		
1) Are winter storms and other special hydrogeological events a major cause of offsite movement of mercury?		
Task 1E:		
1) Unknown sources (other than Harley Gulch and Davis Creek) contribute significant loads of mercury to Cache Creek in the canyon area between the confluences of Cache Creek with the North Fork and Bear Creek.		
Task 2A:		
1) Are mercury levels in tissue from fish in the watershed safe for human and wildlife consumption?		
Task 2B:		
1) Are there ecological risks from mercury bioaccumulation associated with consumption of fish by other top level consumers (avian species in this case)?		
Task 3A:		
1) Mercury and/or mercury and selenium together bioaccumulate to harmful concentrations in avian eggs within portions of the delta or its tributaries.		
Task 3B:		
1) Toxic thresholds differ for mercury in embryos of different avian species; and		
2) Mercury and selenium interactions, while protective in adults birds, are supertoxic to embryos at environmentally realistic but elevated concentrations.		
Task 4A1&2:		
1) There are differences in methyl Hg fluxes between Cache Ck. & Sierra Nevada derived sediments; and		
2) Solid phase Hg washed downstream becomes bioavailable, to differing degrees, when incorporated into a reducing sedimentary environment; and		
3) Benthic macrofauna serve to aggrevate this flux by two processes: a) accelerating the transport of organic carbon to the sediments thereby bringing the oxic/anoxic boundary closer to the sediment/water interface, and b) bioirrigating the sediments, thereby pumping out the products of anaerobic methylation.		
Task 4B1:		
1) Sediments of the upper San Francisco Bay Estuary and Delta region are sites of significant methylmercury production and a dominant source of mercury (as methylmercury) entering the estuarine system.		
Task 4B2:		
1) The supply of bioavailable Hg (as methylmercury) to the upper San Francisco Bay Estuary and Delta region via riverine sources is small compared to that methylmercury produced in situ within the surficial sediments of Delta and upper estuary.		
Task 4B3:		
1) The production of methylmercury in surficial sediments of the estuary varies temporally responding to temperature and other environmental conditions favorable to the activity of sulfate-reducing bacteria.		
Task 5A:		
1) Active and/or abandoned mine sites within the Cache Creek Watershed contain mercury in various forms that can be transported to Cache Creek and beyond; and		
2) Some forms of mercury source materials from these sites have greater potential to produce methyl mercury.		
Task 5B:		
3) There is a predictable relationship between some forms of mercury in water, sediment, aquatic invertebrates and fishes; and		
4) There is a predictable seasonal cycle of bioavailable mercury production and bioaccumulation.		
Task 6: Not applicable		

Task 5B	See below	To develop a predictive relationship between mercury chemistry in water and sediments from various sources (see Subtask A above) with that in biota, data will be collected to characterize environmental mercury chemistry and compare with mercury accumulations in invertebrates and small fishes (used as key *bioindicators*), *both spatially and temporally within the Cache Creek Watershed*, together with additional large fish collections.	Biotic data will be compared with the various mercury sources identified above. This work will (1) document the temporal and spatial variability in mercury biocontamination within the watershed; (2) provide *linkages between sediment/water mercury and biotic mercury and* between useful bioindicators and higher trophic levels, (3) provide mercury data to USF&W to address wildlife concerns (small fish) and OEHHA human health concerns (large fish), *and (4) establish baseline seasonal biotic mercury data* for the watershed so that changes in mercury bioaccumulation may be readily assessed once remediation is undertaken.	

Task 3B	See below	This will be accomplished by working directly with eggs and using egg injection techniques to dose embryos. To do this, investigators led by Dr. Heinz will conduct a progression of studies, culminating in an assessment of the toxic thresholds of methylmercury in the eggs of various fish-eating and other birds.	This work subtask will assess the comparative toxicity of mercury to diverse species of birds, calibrate that toxicity to feeding studies with mallards, and establish risk thresholds for egg residues of fish eating birds as well as other species. This technique has the advantage of being able to assess many species to develop reliable toxicity thresholds for multiple species. Meaningful results for multiple species are expected within the relatively short time period of two years.	
Task 4A1&2	See below	Cache Ck. & Sierra Nevada sediments ("beds") that have known high levels of Hg will be transplanted to different sedimentary regions both in field & lab. MeHg production will be measured by determining flux rates of MeHg from bed's to overlying water & MeHg in beds. Source beds will include fine grain beds from both Cache Ck. & Sac'to River. Receiving bed's will allow for obtaining data along a salinity gradient. Several additional stations will be chosen to reflect different habitat types (differing organic matter, flooded areas, periodically flooded areas such as the Yolo Bypass, different vegetation types, & different tidal heights). Lab experiments will involve bed's from the sources listed above & study variables such as depth of anoxic layer, number of macroorganisms, velocity of water overlying bed's, etc. We will also determine the effect of certain benthic macrofauna on Hg flux by adding organisms (such as *Potamopyrgus amurensis*) directly to the incubated bed samples. & also using killed controls in our design.	Data from this study will measure the flux of Hg between bed's & overlying waters of the Sierra Nevada & Cache Ck drainages, & will provide for an understanding of the role of bed type, diagenetic environment, & benthic macrofauna on Hg flux. Data will be used to determine if the conditions in the new environment accelerates the rates of methylation, as well as the role of microbial activity. The data from this study will be tightly coordinated with those of Gary Gill (TAMUG, Task 7A, B, C, & D) who will measure benthic fluxes directly using benthic flux chambers. The data from this study will provide for a tactical, predictive capability towards understanding the fate of sedimentary Hg & the mechanisms which favor the methylation and transport of the methylated species into the overlying water column.	
Task 4B1	See below	6 stations in the Bay-Delta region will be sampled three times a year using either benthic flux chamber deployments and/or estimated from interstitial pore water gradients (Gill et al., 1999; Mason et al., 1999; Bloom et al., 1999).	The data will be used to determine the sediment to water input flux of Hg & methyl Hg.	
Task 4B2	See below	3 estuarine transects will be conducted to capture varying environmental conditions w/in the estuary & provide maximum riverine source flux ranges. Estuarine transects will be conducted during the spring to early summer period when methylation activity is anticipated to be maximal & during high & low riverine flow periods. To obtain flux information, the estuary will be sampled across a salinity gradient for total & dissolved Hg & methyl Hg.	The data obtained will be modeled using the mass balance geochemical approaches described in Flegal et al. (1991) & Wen et al. (1995) to quantify the riverine inflow, in-situ production (or loss), & estuarine export flux of the Hg forms. This approach will provide an independent estimate to compare with the sediment-water fluxes determined in Task 7A.	
Task 4B3	See below	Sampling will be conducted every 1.5 months for a period of 2 years. Sampling will consist of determining the methyl Hg to total Hg ratio at 6 depths (0, 1, 2, 3, 5, and 10 cm) in sediments & interstitial pore fluids. Sediments & interstitial pore fluids will be collected by sectioning & centrifuging a freshly collected intact core under anaerobic conditions following procedures described by Bloom et al. (1999).	Data will be used to establish the methyl Hg production pattern at a key site in the Bay-Delta region. The site chosen for this study will be coordinated with other CALFED investigations & be one of the sites chosen for Task 7A.	
Task 5A	See below	Total mercury "hot spots" within the Cache Creek Watershed will be identified. At these sites, mercury sources that have the potential to be transported to Cache Creek and beyond will be characterized, quantified and the most abundant chemical forms of mercury will be speciated. We will rely on collaborations with the U.S.G.S. team and others to obtain these data. Lakes/streams that have the potential to carry mercury from these sources will be investigated for loading of the different mercury sources. Once the primary forms of mercury have been identified, selected benchtop studies (microcosm experiments using the methods of Mack et al. 1997) will be used to quantify the potential for each mine source to produce methyl mercury under a variety of in-stream/down-stream environmental conditions.	The primary objective of this work will be to characterize the most important forms of initial source mercury that promote mercury methylation, bioaccumulation, and transfer to higher trophic levels (see Task 5B). This will direct future remedial work to the most appropriate and highly localized sites.	

Table 1. Summary of Ecological/biological objectives, associated hypotheses, and monitoring parameters and approaches

Task Number	Hypotheses/ Questions	Monitoring Parameters And Data Collection Approach	Data Evaluation Approach	Comments
Task 1A&B	See below	Collect total recoverable, dissolved & methyl Hg data along with sediment loads from the 4 rivers. Use this data along with water export rates from each basin to calculate annual sediment & Hg loads to estuary.	Compare estimated loads from each tributary with calculated methyl Hg load produced with estuary to ascertain relative importance of each waterbody. Multiply estimated inorganic load from each watershed by its methylation rate once in estuary to ascertain relative indirect importance of material from each source once in estuary.	Results will be used to focus follow-up remediation feasibility activities on most important watershed sources
Task 1C	See below	Continuous monitoring of stream discharge and turbidity at several gaging stations over 18 months (2 wet seasons, 1 dry season).Water sampling at 12 sites on at least 5 occassions for: unfiltered water (Hg-tot, Hg-Me, tot sed nutrients, trace metals); filtered water (major cations & anions, trace metals, organic carbon, nutrients). Samples of suspended sediment & bed sediment (24 total) will be subjected to sequential extractions to determine chemical/mineralogical forms of Hg.	Loads of Hg-total and Hg-methyl will be computed and compared w/previous work (Foe & Croyle, 1998). Natural contribution from hot springs will be evaluated using natural tracers (e.g. B, Cl). Major anions, DOC, & nutrient data needed to evaluate Hg methylation processes. Major cations & trace metals needed to evaluate overall hydrogeochemistry & origin of other trace elements (e.g. Hg). Standard materials w/Hg in different forms (e.g. sulfide, native element, organically complexed, sorbed to different substrates) will be subjected to same tests.	
Task 1D	See below	The U.S. Geological Survey will install flow gauges on both Creeks and collect general loading information for each tributary (see Subtask 1C above). However, it is felt that additional intensive sampling will be required at each location to document intensive events. Sampling would target winter storms or any other special events identified to be major causes of off site mercury movement.	Data will be used to fully characterize the total and methyl mercury loads, as most material will probably move off during short intense winter storms, which will allow for a determination of total and methyl mercury export.	
Task 1E	See below	Lagrangian water sampling event of tributaries and main stem of Cache Creek in canyon area: unfiltered water (Hg-total, Hg-methyl, total sediment). Filtered water (organic carbon). A total of 12-20 water samples will be collected.	AVIRIS data (mineral maps showing extent of Hg mineralization and related alteration) will be used to prioritize sampling.	Helicopter assistance probably needed to access Cache Creek canyon.
Task 2A & C	See below	A variety of fish species, of varying sizes/ages, will be collected at locations frequently utilized for feeding by wildlife, as well as popular locations for fishermen to fish. The fish shall be processed and analyzed for mercury content. Assessing contamination of several species of small whole body fish within the size range of dietary preference of fish-eating birds is a useful indicator of local degree of risk and bioaccumulation potential of mercury for piscivorous avian species in the watershed.	Data will be used to establish a statistically reliable baseline data to evaluate the effect of mercury remediation and wetland restoration activity in the Basin. DHS and/or OEHHA will evaluate the latest guidelines for Hg in fish and recommend guidelines that will enable us to inform sport/commercial fishermen whether the fish are safe to eat or potentially harmful, recommending consumption frequency and preparation techniques.	
Task 2B	See below	Small whole body fish will likely track changes in water concentration over time and be a useful indicator of changes in biological risk to key species. We will determine the levels of Hg and MeHg in small fish prey and to compare these levels to levels determined to be a safe dose for bird consumption. Dietary preferences will be determined from a literature review and target species will be collected at sites selected by the design committee.	to measure tissue mercury concentrations in fish species which serve as prey items to birds. These concentrations can be compared Hg concentrations in prey items that have been demonstrated to cause toxicity to birds.	
Task 3A	See below	Eggs collected after 8 days of incubation will be assessed for avian developmental abnormalities and anomalies. A variety of nesting aquatic species including rallids, waterfowl, shorebirds and colonial waterbirds will be collected and assessed. The field study will seek to assess 120 eggs/embryos per year, with at least four species represented in each quadrant of the delta and its tributaries in the spring of 1999 and 2000. Where possible nest searches will be conducted in other areas of the delta investigated under other mercury sub-tasks.	The direct assessment of the avian egg has the advantage of demonstrating local bioavailability, as well as providing a direct means of assessing risk, through both chemical concentration determination and embryo assessment. Adverse effects on hatchability, growth, embryo development and post-hatch success will be assessed based upon whole egg concentrations of mercury and/or selenium, utilizing comparisons with results of laboratory studies.	

Table 2: Total Budget (CALFED Funds Only)

Task/Subtask Number	Lead Participant	Direct Labor Hours	Direct Salary & Benefits Costs	Service Contracts Cost	Material & Acquisition Cost	Misc. & Other Direct Cost	Overhead & Indirect Cost	Subtask Total Cost	Task Subtotal Cost
Task 1		***Quantification of Mercury Loads to the Bay-Delta System from Tributary Watersheds***							
Subtask A	Sac Riv Wtrshd								
Subtask B	CVRWQB/SJSUF	1,400	$51,114	$168,572	$0	$23,513	$25,373	$268,572	
Note: $68,572 of funds in Subtask 1B will only be used in 2nd yr if 1st yr sources id'd									
Subtask C	USGS	2,666	$84,712	$0	$10,579	$73,580	$151,129	$320,000	
Subtask D	CVRWQB	0	$0	$30,000	$0	$0	$0	$30,000	
Subtask E	SJSUF*	392	$13,470	$7,200	$0	$19,100	$36,230	$76,000	
Task 1 Subtotal									**$694,572**
Task 2		***Human Health Risk Assessment of Hg in the Cache Creek Watershed***							
Subtask A	SFEI	500	$21,924	$195,000	$0	$3,500	$4,576	$225,000	
Subtask B	SFEI	0	$0	$25,000	$0	$0	$0	$25,000	
Subtask C	OEHHA/DHS	960	$50,970	$0	$0	$5,000	$19,030	$75,000	
Task 2 Subtotal									**$325,000**
Task 3		***Assessment of Hg Hazards to Avian Reproduction in the Sacramento-San Joaquin Delta***							
Subtask A	USFWS	2,322	$72,000	$24,000	$5,500	$500	$23,000	$125,000	
Subtask B	USFWS	1,800	$40,000	$96,000	$38,000	$12,500	$23,500	$210,000	
Task 3 Subtotal									**$335,000**
Task 4		***Assessment of Hg Bioavailability & Flux Rate Throughout the Bay-Delta Watershed***							
Subtask A1	CDFG/SJSUF	7,832	$272,762	$130,000	$36,000	$32,000	$79,238	$550,000	
Subtask A2	SJSUF	2,100	$90,000	$16,680	$30,000	$22,500	$40,820	$200,000	
Subtask B1	TAMUG	4,200	$181,504	$0	$23,500	$63,171	$107,657	$375,831	
Subtask B2	TAMUG	350	$15,165	$0	$1,000	$7,818	$10,112	$34,095	
Subtask B3	TAMUG	0	$0	$0	$0	$28,800	$12,672	$41,472	
Task 4 Subtotal									**$1,201,398**
Task 5		***Hg Sources, Bioaccumulation & Trophic Transfer in the Cache Ck Watershed***							
Subtask A	UC Davis	3,000	$116,030	$40,000	$0	$25,738	$18,177	$199,945	
Subtask B	UC Davis	6,000	$261,420	$55,000	$12,000	$35,475	$35,190	$399,085	
Subtask C1	CDOC/DMG	1,040	$38,739	$0	$0	$10,000	$14,623	$63,362	
Subtask C2	SJSUF*	0	$0	$111,638	$0	$0	$0	$111,638	
Task 5 Subtotal									**$774,030**
Task 6		***Project Management and Logistical Coordination***							
Subtask A	CDFG	3,500	$163,992	$60,000	$0	$5,500	$30,508	$260,000	
Note: $58,500 in service contract category in Task 6A is for SJSUF pass-through overhead (26% of 1st $25,000 x 9 contracts)									
Subtask B	CDFG	725	$30,148	$0	$0	$3,750	$6,102	$40,000	
Subtask C	CDFG/Sac Rv Wtr	498	$20,686	$0	$0	$500	$3,814	$25,000	
Subtask D	CDFG	360	$14,949	$0	$0	$2,000	$3,051	$20,000	
Subtask E	CDFG	90	$3,686	$15,000	$0	$2,500	$3,814	$25,000	
Task 6 Subtotal									**$370,000**
PROJECT TOTAL		**39,735**	**$1,543,270**	**$974,090**	**$166,679**	**$377,445**	**$648,616**	**$3,700,000**	**$3,700,000**

* Funds are to be held at SJSUF until allocated.

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Table 3: Quarterly Budget

Task/Subtask Number	Lead Participant	1st Quarter Cost	2nd Quarter Cost	3rd Quarter Cost	4th Quarter Cost	5th Quarter Cost	6th Quarter Cost	7th Quarter Cost	8th Quarter Cost	Subtask Total Cost	Task Total Cost
Task 1	*Quantification of Mercury Loads to the Bay-Delta System from Tributary Watersheds*										
Subtask A	Sac Riv Wtrshd									Cost share?	
Subtask B	CVRWQB	$75,000	$42,000	$42,000	$41,000	$25,000	$14,524	$14,524	$14,524	$268,572	
Note: $68,572 of funds in Subtask 1B will only be used in 2nd yr if 1st yr sources id'd											
Subtask C	USGS	$88,522	$40,652	$40,652	$20,652	$25,652	$50,652	$45,328	$27,892	$320,000	
Subtask D	CVRWQB	$5,000	$3,400	$3,400	$3,200	$5,000	$3,400	$3,400	$3,200	$30,000	
Subtask E	USGS	$0	$0	$0	$8,000	$8,000	$38,000	$13,000	$11,000	$78,000	
Task 1 Subtotal											$694,572
Task 2	*Human Health Risk Assessment of Hg in the Cache Creek Watershed*										
Subtask A	SFEI	$40,000	$25,000	$24,000	$24,000	$40,000	$24,000	$24,000	$24,000	$225,000	
Subtask B	SFEI	$6,000	$2,800	$2,800	$2,800	$2,800	$2,800	$2,800	$2,200	$25,000	
Subtask C	OEHHA/DHS	$15,000	$8,400	$8,400	$8,400	$10,000	$8,400	$8,400	$8,000	$75,000	
Task 2 Subtotal											$325,000
Task 3	*Assessment of Hg Hazards to Avian Reproduction in the Sacramento-San Joaquin Delta*										
Subtask A	USFWS	$20,000	$10,800	$17,000	$9,500	$22,200	$21,500	$14,700	$9,500	$125,000	
Subtask B	USFWS	$25,500	$19,250	$19,250	$38,000	$33,000	$30,000	$36,000	$11,000	$210,000	
Task 3 Subtotal											$335,000
Task 4	*Assessment of Hg Bioavailability & Flux Rate Throughout the Bay-Delta Watershed*										
Subtask A1	CDFG/MLML	$90,000	$65,000	$65,000	$65,000	$70,000	$65,000	$65,000	$65,000	$550,000	
Subtask A2	MLML	$50,000	$30,000	$20,000	$20,000	$20,000	$20,000	$20,000	$20,000	$200,000	
Subtask B1	TAMUG	$85,000	$42,500	$42,500	$42,500	$55,831	$42,500	$42,500	$42,500	$375,831	
Subtask B2	TAMUG	$10,000	$2,682	$2,682	$2,682	$8,000	$2,682	$2,682	$2,685	$34,095	
Subtask B3	TAMUG	$10,000	$3,912	$3,912	$3,912	$8,000	$3,912	$3,912	$3,912	$41,472	
Task 4 Subtotal											$1,201,398
Task 5	*Hg Sources, Bioaccumulation & Trophic Transfer in the Cache Ck Watershed*										
Subtask A	UC Davis	$30,000	$30,000	$25,000	$25,000	$25,000	$25,000	$20,000	$19,945	$199,945	
Subtask B	UC Davis	$70,000	$60,000	$50,000	$50,000	$50,000	$40,000	$40,000	$39,085	$399,085	
Subtask C1	CDOC, DMG	$0	$0	$0	$0	$25,362	$12,750	$12,750	$12,500	$63,362	
Subtask C2	MLML--temp	$0	$0	$0	$0	$40,838	$24,000	$24,000	$23,000	$111,638	
Task 5 Subtotal											$774,030
Task 6	*Project Management and Logistical Coordination*										
Subtask A	CDFG	$85,000	$25,000	$25,000	$25,000	$25,000	$25,000	$25,000	$25,000	$260,000	
Note: $60,000 in Task 6A is for SJSUF pass-through overhead (26% of 1st $25,000 x 8 contracts)											
Subtask B	CDFG	$10,000	$5,000	$2,500	$2,500	$10,000	$5,000	$2,500	$2,500	$40,000	
Subtask C	CDFG/Sac Rv Wtr	$5,000	$2,500	$2,500	$2,500	$5,000	$2,500	$2,500	$2,500	$25,000	
Subtask D	CDFG	$4,000	$2,000	$2,000	$2,000	$4,000	$2,000	$2,000	$2,000	$20,000	
Subtask E	CDFG	$5,000	$2,500	$2,500	$2,500	$5,000	$2,500	$2,500	$2,500	$25,000	
Task 6 Subtotal											$370,000
PROJECT TOTAL		$889,022	$423,196	$401,098	$387,148	$521,483	$466,120	$427,494	$374,443	$3,700,000	$3,700,000

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Table 4: Schedule of Task Activities/Milestones

Task/Subtask Number	Lead Participant	Activity or Milestone	Quarter Number									
			Yr 1				Yr 2				Yr 3	
			1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
Task 1	***Quantification of Mercury Loads to the Bay-Delta System from Tributary Watersheds***											
Subtask A	Sac Riv Wtrshd	Collect Sac Rv samples for total Hg, MeHg	x	x	x	x	x	x				
		Sample analysis		x	x	x	x	x	x			
		Data & QA/QC reporting			x		x		x			
Subtask B	CVRWQB/MLML	Collect other river samples for total, dissolved, & MeHg	x	x	x	x	x	x				
		Sample analysis		x	x	x	x	x	x			
		Data & QA/QC reporting			x		x		x	x		
Subtask C	USGS	Construct & instrument gaging stations in study area	x									
		Operate & maintain gaging stations (18 months)	x	x	x	x	x	x				
		Monitor water quality & Hg speciation (5 sampling periods)		x	x	x	x	x				
		Data & QA/QC reporting			x		x		x	x		
Subtask D	MLML/CVRWQB	Collect storm/special event samples for total Hg, MeHg		x				x				
		Sample analysis			x				x			
		Data & QA/QC reporting			x				x	x		
Subtask E	USGS	Reconnaissance investigation of study site					x					
		Conduct sample collection						x	x			
		Sample analysis							x			
		Data & QA/QC reporting							x	x		
Task 2	***Human Health Risk Assessment of Hg in the Cache Creek Watershed***											
Subtask A	SFEI	Design fish study--species, sizes, analytical methods, etc.	x	x								
		Collect samples & analyze		x	x	x	x	x				
		Data & QA/QC reporting			x		x		x			
Subtask B	SFEI	Design prey fish study--species, sizes, analytical methods, etc.	x	x								
		Collect samples & analyze		x	x	x	x	x				
		Data & QA/QC reporting			x		x		x			
Subtask C	OEHHA/DHS	Meet w/fish Task participants & review data	x	x		x		x		x	x	x
		Produce tissue consumption guideline report								x	x	x
		Issue advisories if appropriate				x		x		x		x
Task 3	***Assessment of Hg Hazards to Avian Reproduction in the Sacramento-San Joaquin Delta***											
Subtask A	USFWS	Conduct site & species reconnaissance	x	x								
		Conduct field sampling/egg collection		x	x			x	x			
		Assess 120 eggs from 4 species/yr for avian developmental			x				x			
		abnormalities & Hg &Se tissue concentrations										
		Data & QA/QC reporting				x	x			x	x	x
Subtask B	USFWS	Conduct egg injection studies	x	x	x	x	x	x	x	x		
		Data & QA/QC reporting		x		x		x		x		
Task 4	***Assessment of Hg Bioavailability & Flux Rate Throughout the Bay-Delta Watershed***											
Subtask A1	CDFG/MLML	Conduct site reconnaissance/50 station habitat survey	x	x								
		Conduct sample collection (3 periods)		x		x		x				
		Sample analysis			x		x		x			
		Data & QA/QC reporting				x		x		x		
Subtask A2	MLML											
Subtask B1	TAMUG	Conduct site reconnaissance	x									
		Collect samples from 6 stations in Bay-Delta for sediment		x	x	x		x	x	x		
		to water input flux of Hg& MeHg (3x/yr to assess temp. var.)										
		Sample analysis			x	x	x		x	x	x	
		Data & QA/QC reporting					x				x	
Subtask B2	TAMUG	Conduct 2 estuarine transects to capture extremes in riverine flow			x			x				
		(across salinity gradient for total, dissolved, & Me Hg from										
		Sacramento to the Golden Gate)										
		Sample analysis				x			x			
		Data & QA/QC reporting					x			x		
Subtask B3	TAMUG	Conduct sampling every 1.5 mo for duration @ 8 depths	x	x	x	x	x	x	x	x		
		(0, 1, 2, 3, 5, and 10 cm) in sed's & interstitial pore fluids										
		Determine MeHg to total Hg ratio at each depth (samp analysis)		x	x	x	x	x	x	x	x	
		Data & QA/QC reporting			x		x		x		x	

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Table 4: Schedule of Task Activities/Milestones

Task/Subtask Number	Lead Participant	Activity or Milestone	Quarter Number									
			Yr 1				Yr 2				Yr 3	
			1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
Task 5	***Hg Sources, Bioaccumulation & Trophic Transfer in the Cache Ck Watershed***											
Subtask A	UC Davis	Site reconnaissance & selection/mapping	x	x								
		Conduct sample collection		x	x	x	x	x	x			
		Sample analysis			x	x	x	x	x	x		
		Data & QA/QC reporting			x		x		x		x	
Subtask B	UC Davis	Conduct sample collection		x	x	x	x	x	x			
		Sample analysis			x	x	x	x	x	x		
		Data & QA/QC reporting				x		x		x		
Subtask C1	CDOC/DMG	Conduct mine site assessments					x	x	x			
		Prepare documentation of mine site assessments								x	x	
Subtask C2	SJSUF-Temp	Contingency project if Hg identified						x	x	x	x	x
Task 6	***Project Management and Logistical Coordination***											
Subtask A	*CDFG*	*Prepare & manage subcontracts*	x	x	x	x	x	x	x	x	x	x
		Prepare & submit invoices	x	x	x	x	x	x	x	x	x	x
Subtask B	CDFG	Plan & conduct Qtrly Project Status Meetings/Conf Calls	x	x	x	x	x	x	x	x	x	x
		Prepare project-wide Quarterly Progress Report	x	x	x	x	x	x	x	x	x	x
		Prepare project-wide Annual Project Report				x	x					
		Prepare project-wide Draft & Final Project Report								x	x	x
Subtask C	CDFG	Develop sampling, safety, & QAPP for entire project	x	x								
		Develop standardized data reporting formats w/all participants	x	x								
		Compile data QA/QC evaluative reports & data reports			x		x		x		x	x
		for all participants, review, & submit										
Subtask D	CDFG/Sac River	Preparation & distribution of informational newsletter		x		x		x		x		x
	Watershed	Plan & conduct seminar series @ UCDavis		x		x		x		x		x
		Plan & conduct outreach workshops/forums		x			x					x
Subtask E	CDFG	Form *external review committee (ERC)*	x									
		Conduct ERC meeting	x				x					x
		Prepare summary of ERC comments & responses	x				x					x
The following activities/products are required of all participants for all tasks/subtasks (except Task 6) and are not included in the above task-specific schedule:												
All tasks/subtasks	All participants	Develop sampling, safety, and quality assurance plans	x	x								
All tasks/subtasks	*All participants*	*Prepare & submit Quarterly Progress Reports & Invoices*	x	x	x	x	x	x	x	x	x	x
All tasks/subtasks	All participants	Prepare & submit Annual Project Report					x					
All tasks/subtasks	All participants	Prepare & submit Draft & Final Project Report									x	x
All tasks/subtasks	All participants	Participate in Quarterly Project Status Meeting/Conf Call	x	x	x	x	x	x	x	x	x	x
All tasks/subtasks	All participants	Participate in External Review Committee meetings	x				x					x
All tasks/subtasks	All participants	Participate in scientific forums, conduct presentations, &		x		x		x		x		x
		develop publications as appropriate										

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